# Recent Progress in Satellite Data Assimilated 4D Global Precipitation Products

## From the GEOS System

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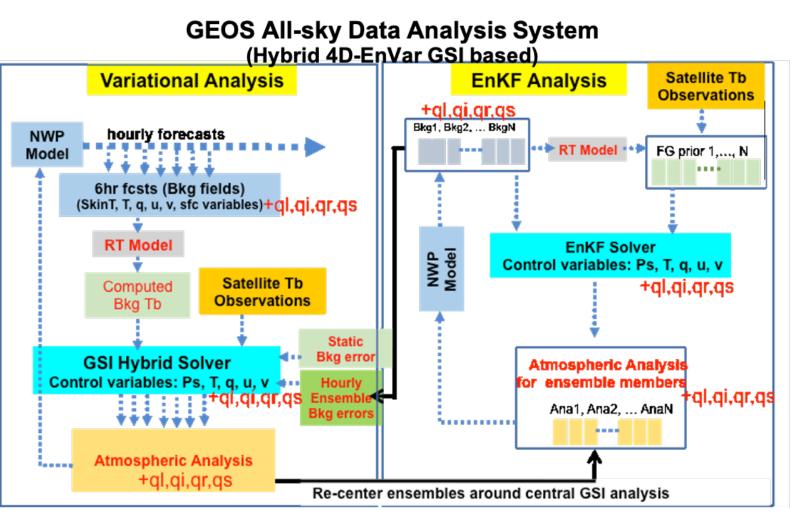


### **Goddard Earth Observing System (GEOS)**

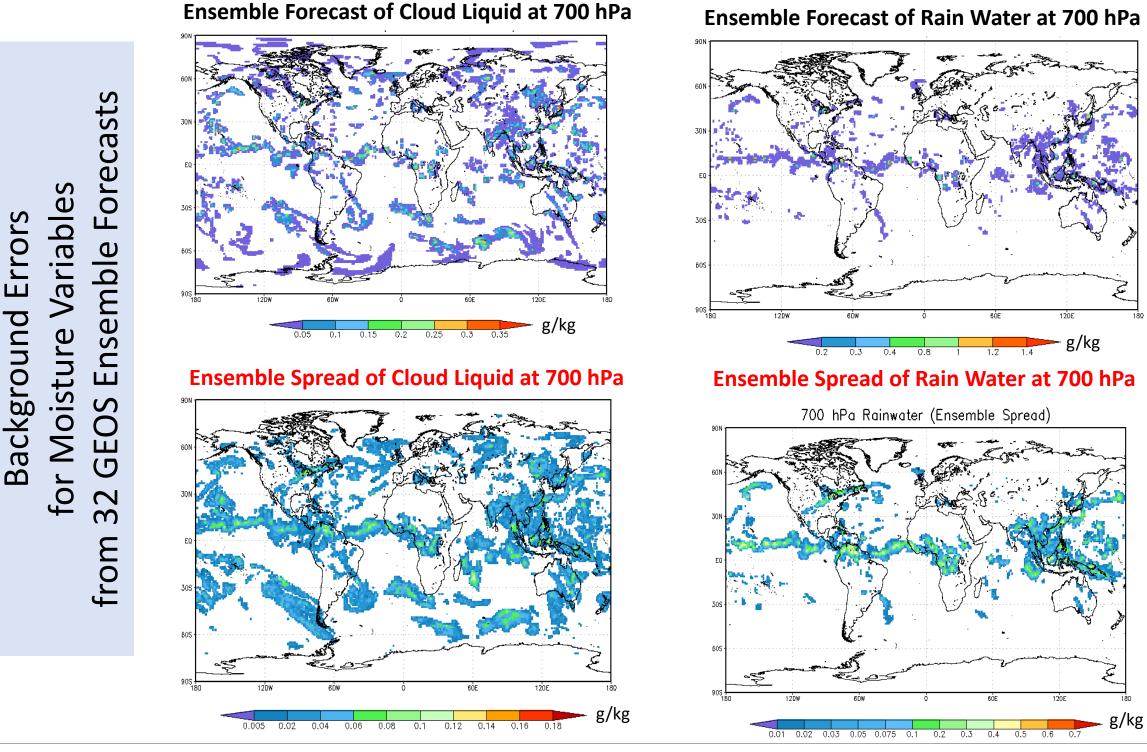
GEOS is the main system that is used for applications across a wide range of spatial scales, from kilometers to many tens of kilometers. The system consists of a group of model components such as Atmospheric General Circulation Model (AGCM, Ocean General Circulation Model (OGCM), Chemistry-Climate Model (CCM), Chemistry Transport Model (CTM), etc.

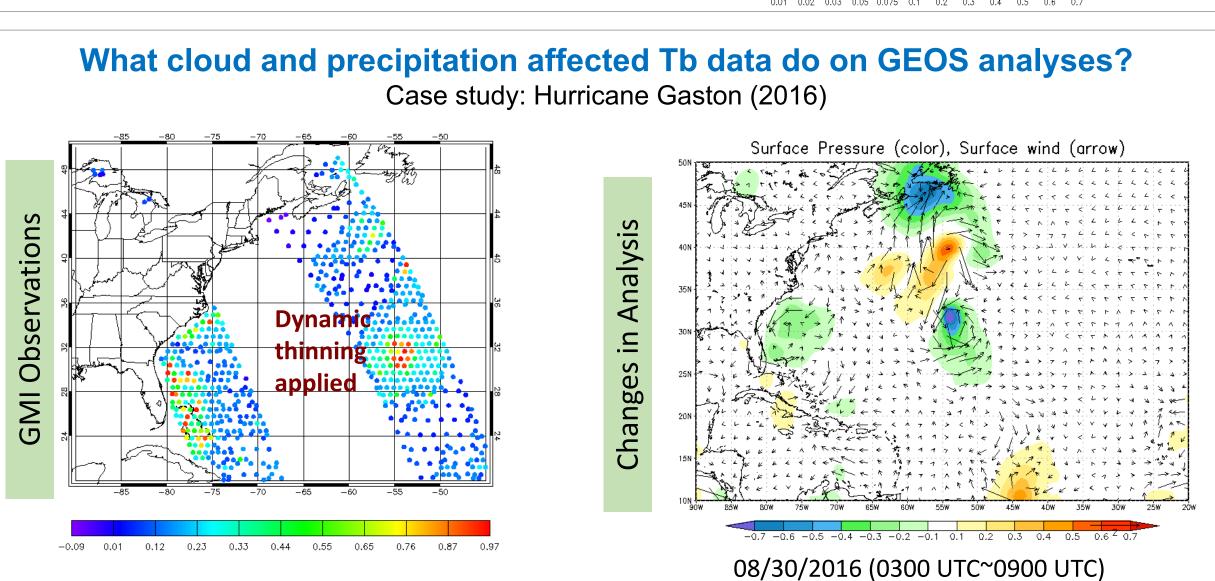
			Observ	ing system	in GEOS-FP				
Satellite Radiance			Satellite Retrieved			Satellite Retrieved (cont'd)			
Red denotes new	AMSU-A	NOAA-15 NOAA-18 NOAA-19 Metop-A	•	Geo AMV	GOES-16 GOES-17 Meteosat-8 Meteosat-11		•	Ozone SNPP AOD	Aura Terra Aqua
	<ul> <li>ATMS</li> <li>MHS</li> <li>GMI</li> <li>SSMIS</li> <li>AMSR-2</li> </ul>	Metop-B Metop-C SNPP NOAA-20 Metop-B Metop-C GPM F17		Polar AMV NOAA-18 NOAA-19 Scat Wind GNSS RO	Metop-A Metop-B Terra Aqua ASCAT COSMIC (1) COSMIC-2 (5) Metop-A Metop-B Metop-C TerraSAR-X TanDEM-X	Cor	nven	Radiosonde Dropsonde Pibal Aircraft Marine Sfc Land Sfc	u,v,T,q,p u,v,T,q u,v u,v,T u,v,T,p p
	AIRS     CrIS     IASI     AVHRR	GCOM-W Aqua NOAA-20 SNPP Metop-A Metop-B NOAA-18 Metop-A				5)	~5.5 M obs/cycle (up from ~4.5 M in curr		

#### **GEOS Atmospheric Data Assimilation System**



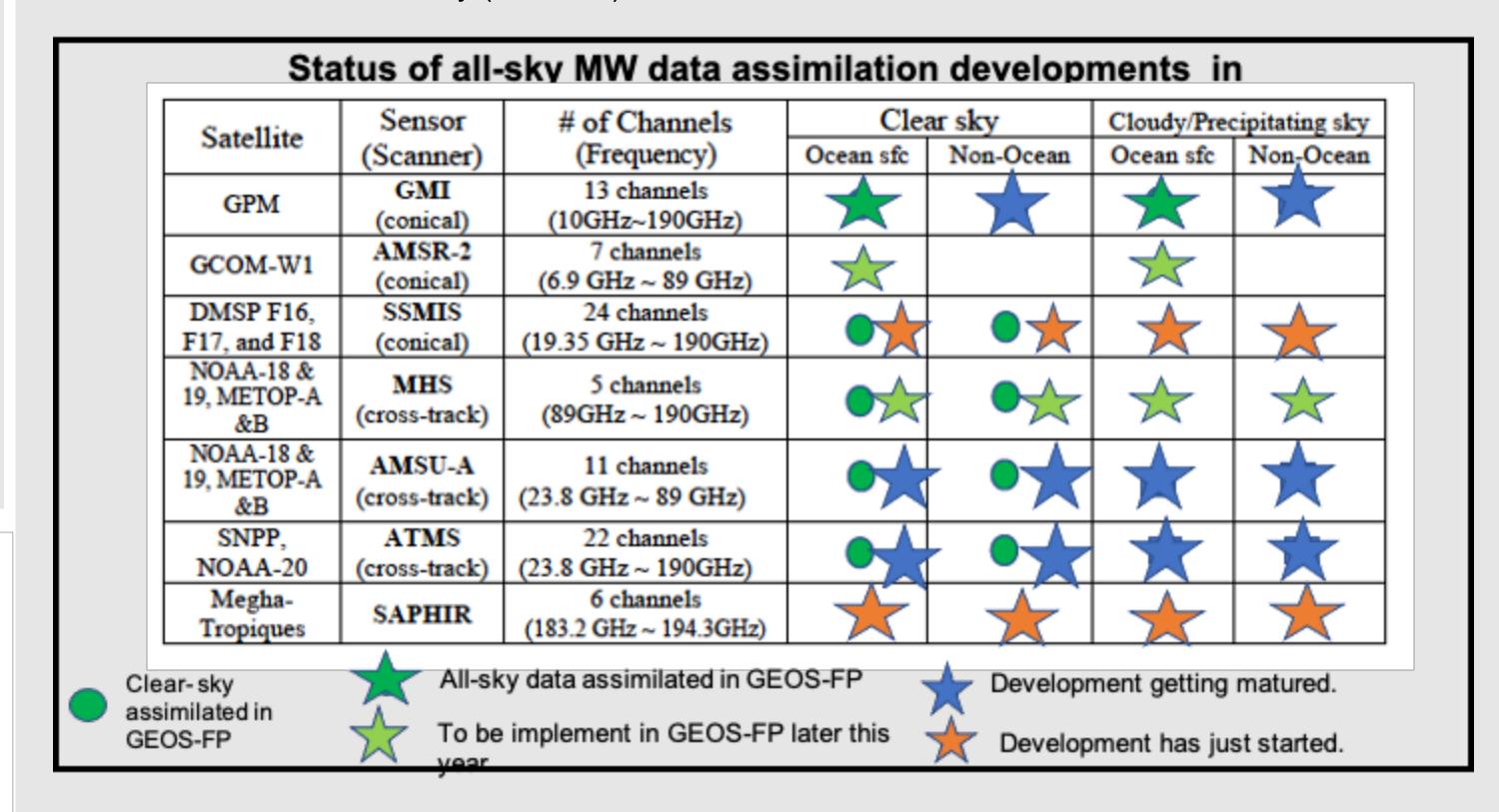
- Significant changes were made in GEOS to assimilate cloud and precipitation affected radiance data (Kim et al. 2020, MWR).
- Four new state and analysis control variables were added for hydrometeors (liquid cloud, ice cloud, rain, and snow)
- Background error for these hydrometeors are generated and used.
- Observation error models (symmetric error model, Geer and Bauer 2011) were built and tuned.
  Bias correction and quality control procedures for all-sky microwave radiance data were developed.
- Enhanced radiance observation operator, Community Radiative Transfer Model (CRTM)



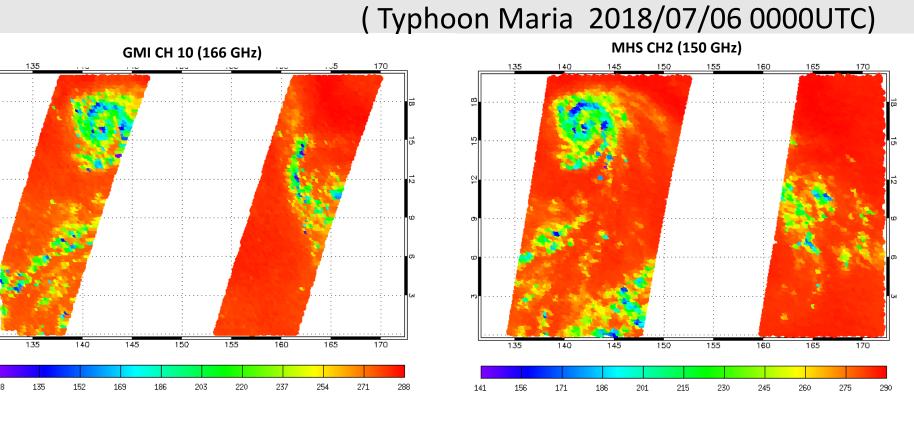


### **Extending All-sky System to Other Microwave Data for GEOS-FP upgrades and next NASA reanalysis**

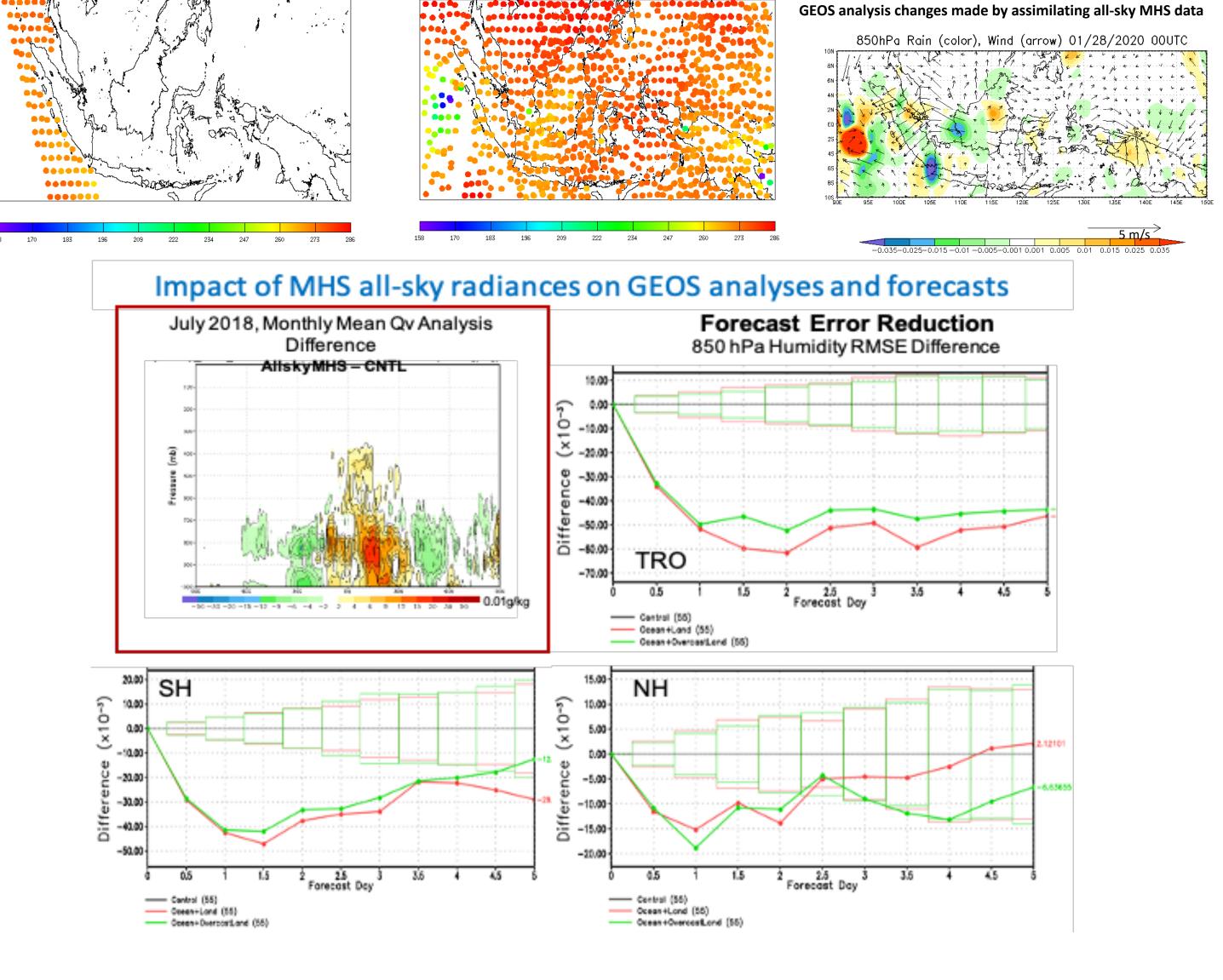
To maximize the benefits, the all-sky system is being adapted to assimilate more data from other microwave sensors such as AMSR2/GCOME-W, Microwave Humidity Sounder (MHS), Advanced Microwave Sounding Unit (AMSU-A), Advanced Technology Microwave Sounders (ATMS), and Special Sensor Microwave Imager/Sounder (SSMIS), and Sounding for Probing Vertical Profiles of Humidity (SAPHIR).



### Comparisons of Observed All-sky Brightness Temperatures

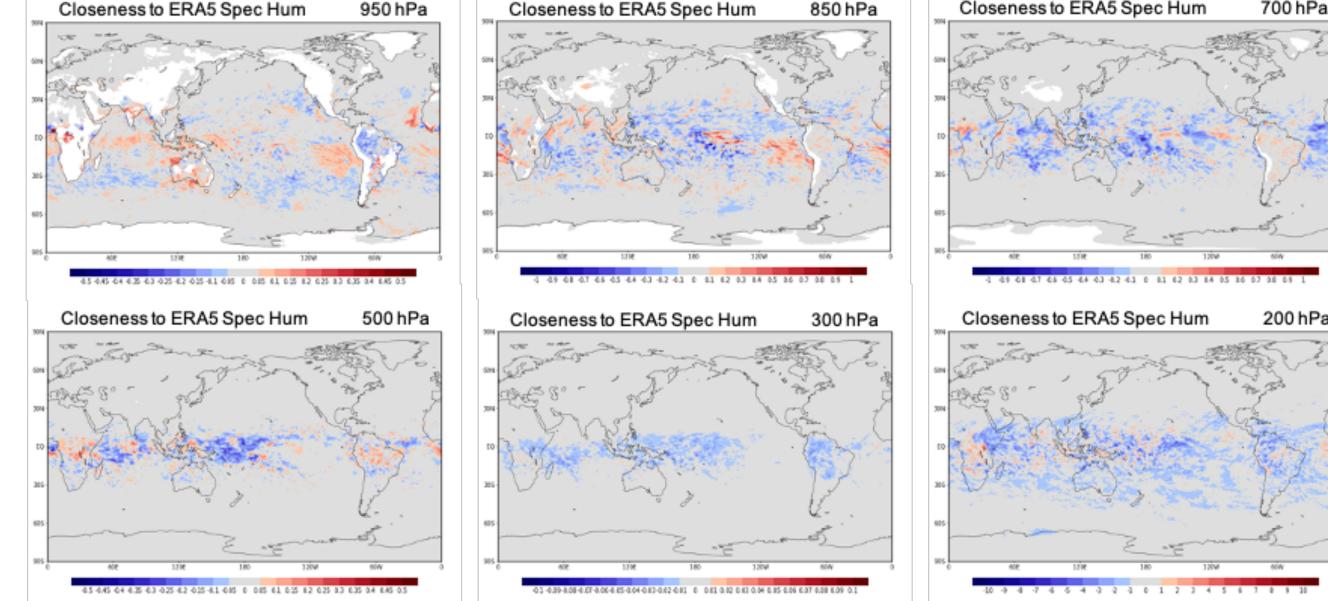


GMI and MHS both have channels near 183 GHz water vapor absorption band therefore provide us similar information about storms. However, MHS sensors are in multiple satellites (better temporal resolution) and has better spatial due to its wider swath width.



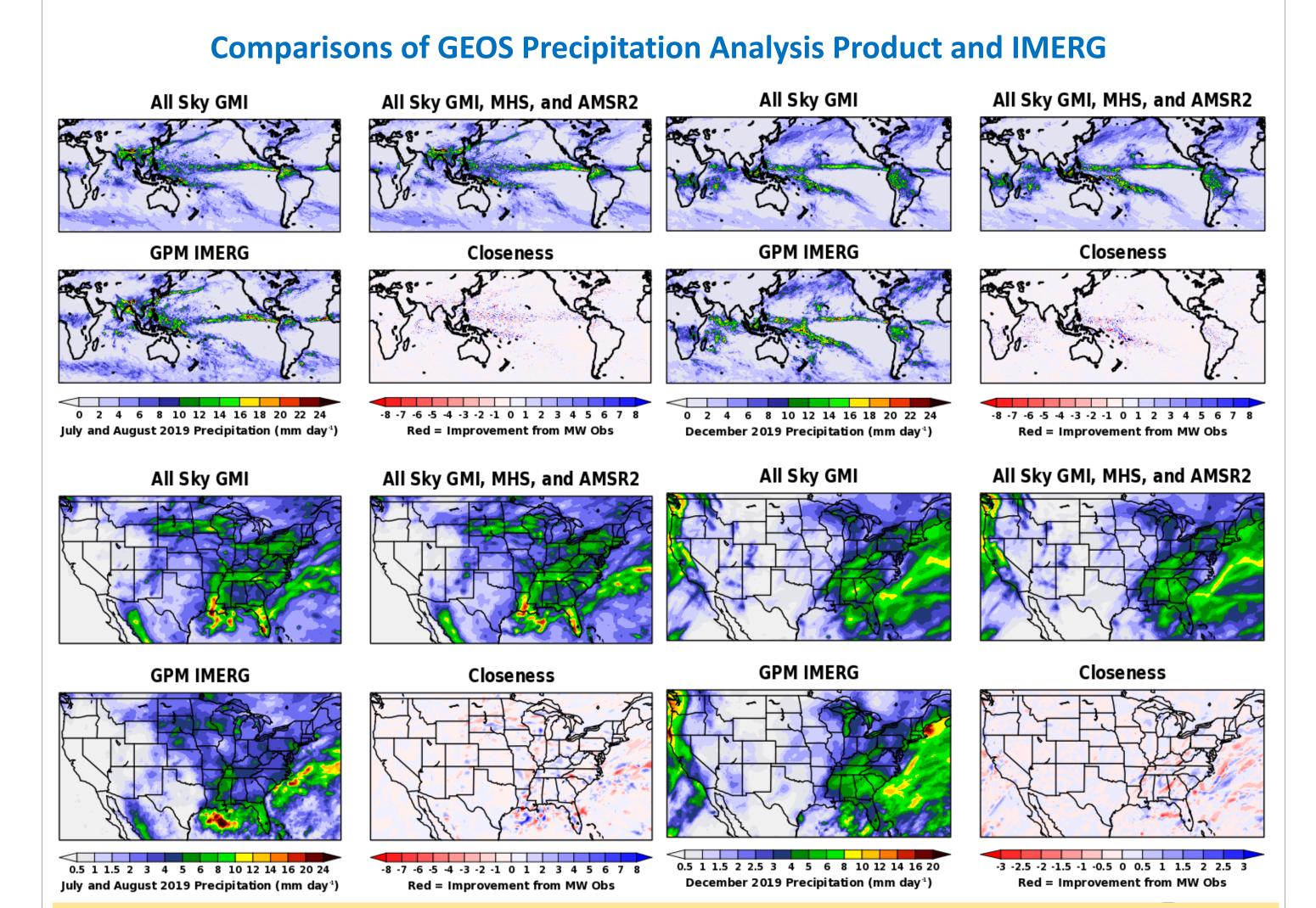
### Closeness to ERA5 vs. operational control: specific humidity (g/kg)

01Dec-31Jan 2019/20 All-sky MHS/AMSR2+COSMIC2 GEOS vs. Current GEOS (blue: All-sky MHS/AMSR2+COSMIC2 GEOS closer to ERA5)



#### Forecast Skill Improvements of GEOS including all-sky GMI, MHS, and AMSR2

Northern Hemisphere					n Hemisphere	2	Tropics				
Variable	Pressure Level	COR	RMS	Variable	Pressure Level	COR	RMS	Variable	Pressure Level	COR	RMS
Forecast	Forecast Day		12345	Forecast	Forecast Day		12345	Forecast	Day	12345	12345
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	500	<b>▲</b> A./3	<b>▲▲▲</b> ∧,/(2018/00)		500	99	Λ	- Trongini	500	AAAAAAAA	****
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	100	****	AAA 18		100	AAAAASSAIII	AAS SVEV	Specific	100	A 23 23	Δ
	250	323	88 EAS		250	ANSWAAA	ASASAAA	Specific Humidity	250	₩ SEE RESA	***** A
	500	385/68 85 <b>44</b>	2081/A28		500	manana.	IIIX/AAAAAA		500	AAAAAA	=*****
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	850	AAAAAA BIII	<u>▲</u> ∧∧∧∧∧±866 <u>▲</u> ∧∧∧∧√±866		850	20 10 10000	1000400		850	AAAAAAAA	2
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	70	AAGA	AATA		70		1000000		70	- A	AA.
	100	AAAAA	***	U-Wind	100	SANANNA	A4440400		100	2020	10000
	250	AAAA8	AAAAASII III		250	AAAASSAAA	*****	U-Wind	250	AAAAAARRAA	AAAAARRII A
	500	AAAAS ESS	AAAA8 888		500	A000	AARA		500	*****	AAAAAA8888
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### Work in progress

- Delivering 1-year long GEOS precipitation analysis products from the next GEOS-FP system assimilating all-sky GMI, MHS, and AMSR-2 (possibly available to PMM Science Team by late2020/early 2021)
- Developing precipitation analysis products from GEOS assimilating all-sky ATMS, SSMIS, and AMSUA
   Developing GEOS Downscaling precipitation analysis products (7km) for 2015/12-2016/01 (OLYMPEX period).